UNCLASSIFIED

AD NUMBER
AD476768
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 30 OCT 1964. Other requests shall be referred to Naval Ordnance Lab., White Oak, MD.**
AUTHORITY
USNOL ltr dtd 29 Aug 1974

THIS PAGE IS UNCLASSIFIED

AD-467964

NOLTR 64-206

NOL TR-64-206 c.1

OUTPUT TESTS OF DRIVER, EXPLOSIVE BELLOWS MK 15 MOD 0

30 OCTOBER 1964

NOL

UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

NOLTR 64-206

NOTICE

Requests for additional copies by Agencies of the Department of Defense, their contractors, and other Government agencies should be directed to:

Defense Documentation Center (DDC)
Cameron Station
Alexandria, Virginia

Department of Defense contractors who have established DDC services or have their 'need-to-know' certified by the cognizant military agency of their project or contract should also request copies from DDC.

OUTPUT TESTS OF DRIVER, EXPLOSIVE BELLOWS Mk 15 Mod 0

Prepared by:
Sherman L. Min

ABSTRACT: Force-displacement curves for the Mk 15 explosive driver were determined by measurement in a test fixture simulating a particular ordnance application. One hundred units were tested and variability of output was determined. The variability and shape of the force-displacement curves indicate the importance of close control of initial positioning of the driver relative to the parts it operates in such an application.

PUBLISHED FEBRUARY 1966

U. S. NAVAL ORDNANCE LABORATORY
White Oak, Maryland

NOLTR 64-206 30 October 1964

OUTPUT TESTS OF DRIVER, EXPLOSIVE BELLOWS Mk 15 Mod 0

This report presents the results of tests providing characteristic data on the Driver, Explosive Bellows Mk 15 Mod 0 which should be of general use to design engineers. The specific work was required in connection with the employment of this driver in the unlocking device for the POLARIS Mk 2 AFD and was performed under Task No. NOL 417 S/P from the Special Project Office. The opinions and judgments expressed are those of the Air and Surface Mechanical Engineering Department.

J. A. DARE
Captain, USN
Commander

J. H. Armstrong
J. H. ARMSTRONG
By direction

CONTENTS

ILLUSTRATIONS

TABLE

INTRODUCTION

1. Failures in the decelerometer unlock of the POLARIS Mk 2 Arming and Fuzing Device (AFD) resulted in the work described herein. Additional gap-test failures (gap between the driver and a paddle-shaped arm of the unlocking device) found at the Naval Ordnance Laboratory, White Oak (NOL(WO) have indicated the need for more information on the driver output. Tests showed that the existence of a .010" or larger gap caused failures. In order to assure that a single driver has the capability of unlocking the decelerometer, the performance of the driver was investigated and the output test was developed.

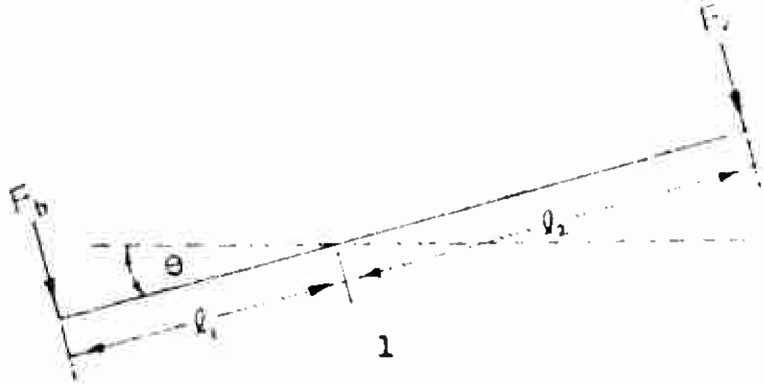
2. Hercules Powder Company, contractor for the subject driver, presented a test method where a linear driver output was measured without the frictional force which is encountered in the unlocking device. Although this method should give useful data, it does not solve the gap problem mentioned above.

3. The test fixture shown in Figure 1 gives data for a plot of torque vs angular displacement of the driver in a simulated unlocking device, Figure 4. This plot, with the superimposed decelerometer-unlock operational curve, defines the maximum allowable gap between the driver and the paddle in the unlock. Consequently, the graph indicates the torque required of the driver to assure reliable operation.

THEORETICAL ANALYSIS

4. The output of the driver, as a function of its angular displacement, can be determined by actuating it against a constant load. This load should be sensed by the driver constantly whether it is in motion or at rest. This constant load was obtained by using a "negator" spring which gives a noncumulated force at any length of the spring. The system was proved to be stable by using a high-speed movie camera.

5. Based on the assumption that the force, F_b, produced by a driver is always normal to the paddle, the system shown in Figure 1 can be represented by a simple free-body diagram as shown below.



Force F_v is the normal component of the spring force F_s, and θ is the angular displacement caused by the driver. Lengths l_1 and l_2 are the moment arms for the driver and the spring respectively. Length l_2 is four times greater than l_1 to allow a smaller spring force and easier assembly. When the system is in equilibrium, after driver actuation, the torque T created by the driver is equal to that of the spring. It follows:

$$T = \ell_1 F_b = \ell_2 F_v \qquad (1)$$

From Appendix A, equation (1) becomes

$$T = \ell_2 F_s \cos\left\{17.5^\circ + \frac{\theta}{2} - \sin^{-1}\left[\frac{.074}{\sin\left(\frac{\theta+35^\circ}{2}\right)}\right]\right\} \qquad (2)$$

Thus, torque T can be computed from equation (2) or it can be determined by a torque wrench with respect to θ.

6. In order to analyze the effect caused by the gap between the driver and the paddle in the unlock, the angular displacement has been converted to linear displacement along its curved path as shown in Appendix C. Prior to the work described in this report, a maximum gap of .145" could exist in the unlock. The latest revision to the unlock specification allows a maximum gap of .035". A theoretical plot with respect to these two gaps indicates the reliability of the driver.

PROCEDURE

7. One-hundred drivers were serialized and their bridge-wire resistances and insulation resistances were recorded. These values were within the specification (WS 1905). The specimens were then subjected to x-ray examination. No defects were found and the specimens were ready for the output test.

8. The test driver was placed in the test fixture in such a way that the front end of the driver was in contact with the paddle. A negator spring with a known spring force was attached to the other end of the paddle. Five different values of spring force were used and twenty drivers were subjected to each spring force. Thus, each spring force determined a point on the output curve.

9. An electrical signal of 4 volts d.c. with one millisecond pulse was used to fire the drivers in accordance with WS 1905F, paragraph 3.4.2.6. The circuit diagram for the test is shown in Figure 2. This diagram shows that the high-speed movie camera (6000 frames per second) closed the circuit. In turn, the pulser generated the required electrical signal to actuate the driver. An oscilloscope was used for visual inspection of the pulse. A typical pulse is shown in Figure 3.

RESULTS

10. Test data are listed in Table 1 and the output curves are shown in Figure 4. It was observed that the variations in the angular displacements of the drivers had large ranges. The standard deviations σ (see Appendix B) were found to be $\pm 6.83^\circ$, $\pm 12.2^\circ$, $\pm 8.34^\circ$, $\pm 5.90^\circ$ and $\pm 4.63^\circ$ for spring forces of 3.70 lbs, 4.49 lbs, 4.80 lbs, 5.47 lbs, and 6.60 lbs. respectively.

11. By measuring 30 drivers, it was found that one third of them were oversized in length. The lengths were approximately .015" longer than the 1.000" maximum specified on BUWEPS drawing 2415726.

DISCUSSION

12. Figure 4 shows that the critical point for the unlock is at 25° and 7 in-lbs torque. However, the lowest torque found from the test at that particular angle was 9 in-lbs and the average torque at that angle was 11 in-lbs (without gap). For the average values, the factor of safety S at the critical point is (assuming no gap):

$$S = \frac{\text{output torque}}{\text{working torque}} = \frac{11}{7} = 1.57$$

For the lowest values

$$S = \frac{9}{7} = 1.28$$

Of course, if both drivers are actuated simultaneously and operated independently in the unlock, the safety factor would be doubled.

13. However, the existence of a .035" separation between the driver and the paddle in the unlock would cause the output curve in Figure 4 to shift .035", or about 5°, toward the axis of

ordinates. The shift is justified because the driver will not sense the 7 in-lbs load until it travels the full gap. The gaps are expressed in terms of linear displacement and the relationship between the linear and angular displacements is expressed in Appendix C. It can be seen from the graph that a large amount of energy is wasted because of the spacing. Theoretically, a .145" spacing output curve would pass through the critical point. It is believed that this is a factor that caused the driver to fail to complete its operation during certain operational tests.

14. High speed movies were used to record the angular displacement accurately. After being fired, the driver was annealed by the hot gas and the spring force caused it to retreat immediately as much as 7°.

15. The test fixture cavity wall finish was simulated to the "as cast" finish of the unlock. Therefore the wall friction force which restrained the driver movement is included in the output curves. After the driver's output tests the unlock cavity finish was changed to a 25-40 microinch finish, and a dry film lubricant is required to be applied to the cavity and the paddle bearing surfaces. Thus the driver's output in the latter conditions would be increased.

16. Large values in standard deviation, σ, observed from the test could be explained as follows:

a. The wall thickness of the extendable portion of the driver was not uniform. A thinner wall has less restraining force. Also, the physical properties of the bellows probably vary from unit to unit.

b. From a thermodynamic viewpoint, the pressure generated inside the driver is inversely proportional to the volume. Thus, oversized drivers produced less pressure.

c. Even though the explosives used in the drivers were weighed, inherent variations in chemical content are unavoidable.

RECOMMENDATIONS

17. Based on the above discussion, the following actions are recommended:

a. Avoid spacing between the driver and the paddle in the unlock by selective assembly.

b. Tighten the contractor's quality control on the driver and all components associated with it in the unlocking device.

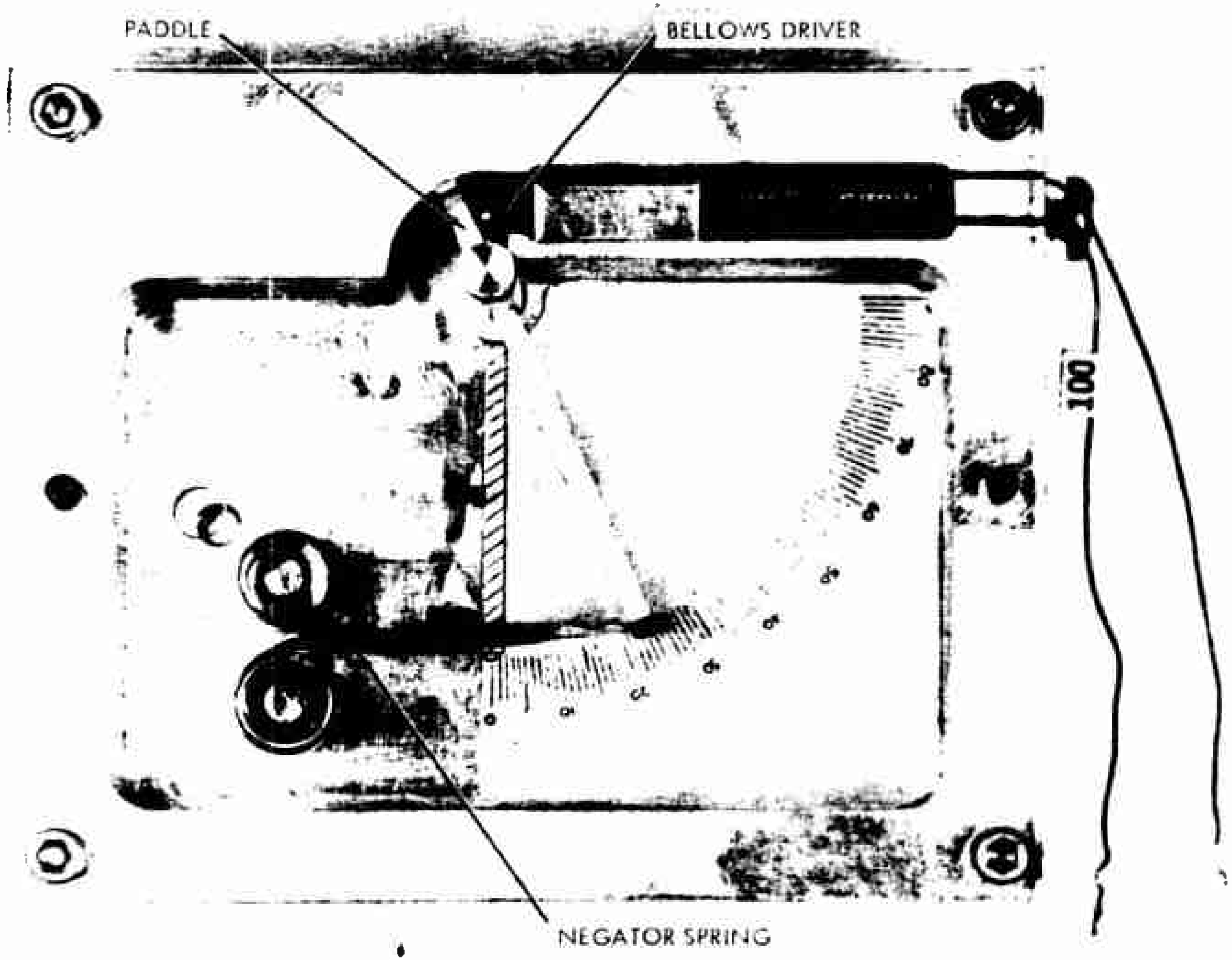


FIG. 1 BELLOWS DRIVER OUTPUT TEST FIXTURE

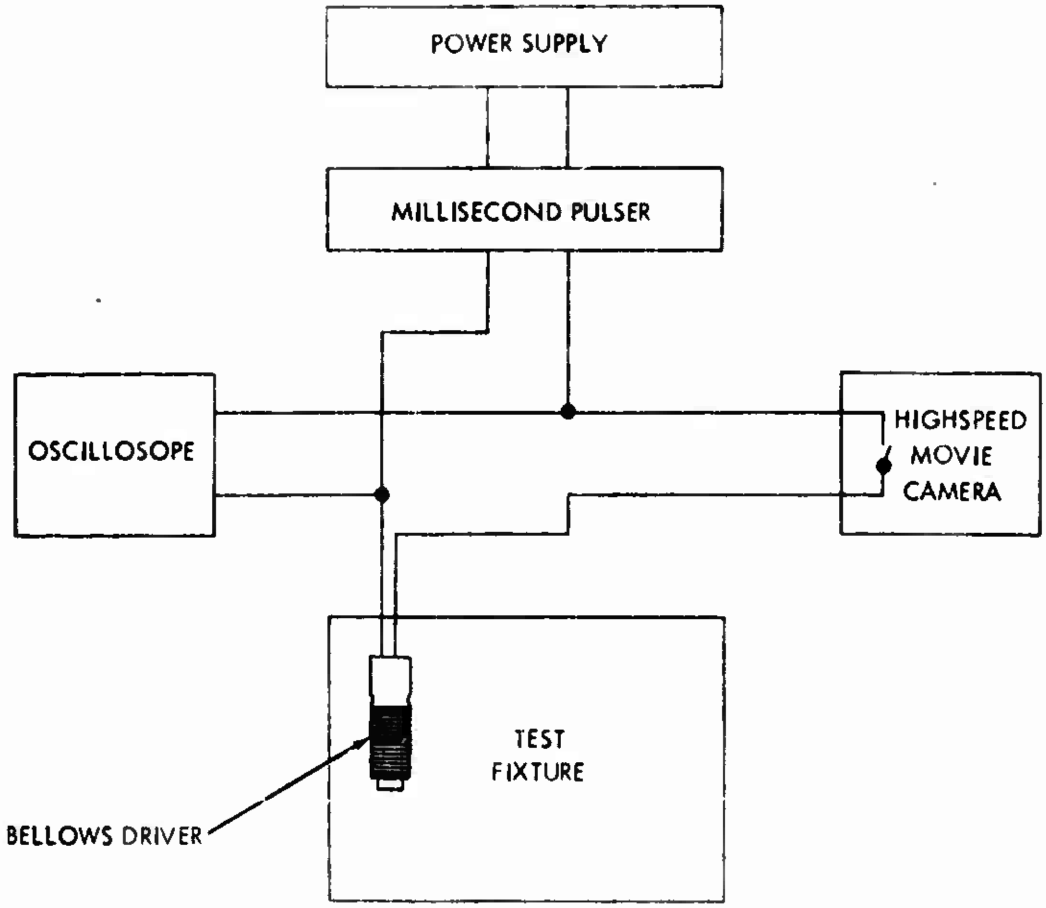
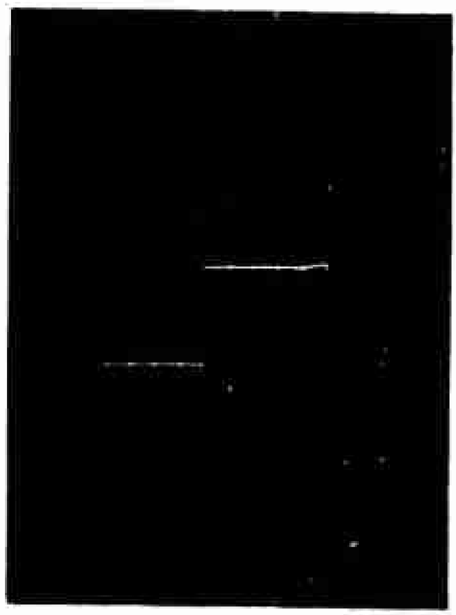


FIG. 2 BELLOWS DRIVER OUTPUT TEST CIRCUIT DIAGRAM



PULSE – 1 VOLT/CM

SWEEP – 0.2 MS/CM (FROM RIGHT TO LEFT)

FIG. 3 TRACE OF BELLOWS DRIVER FIRING SIGNAL

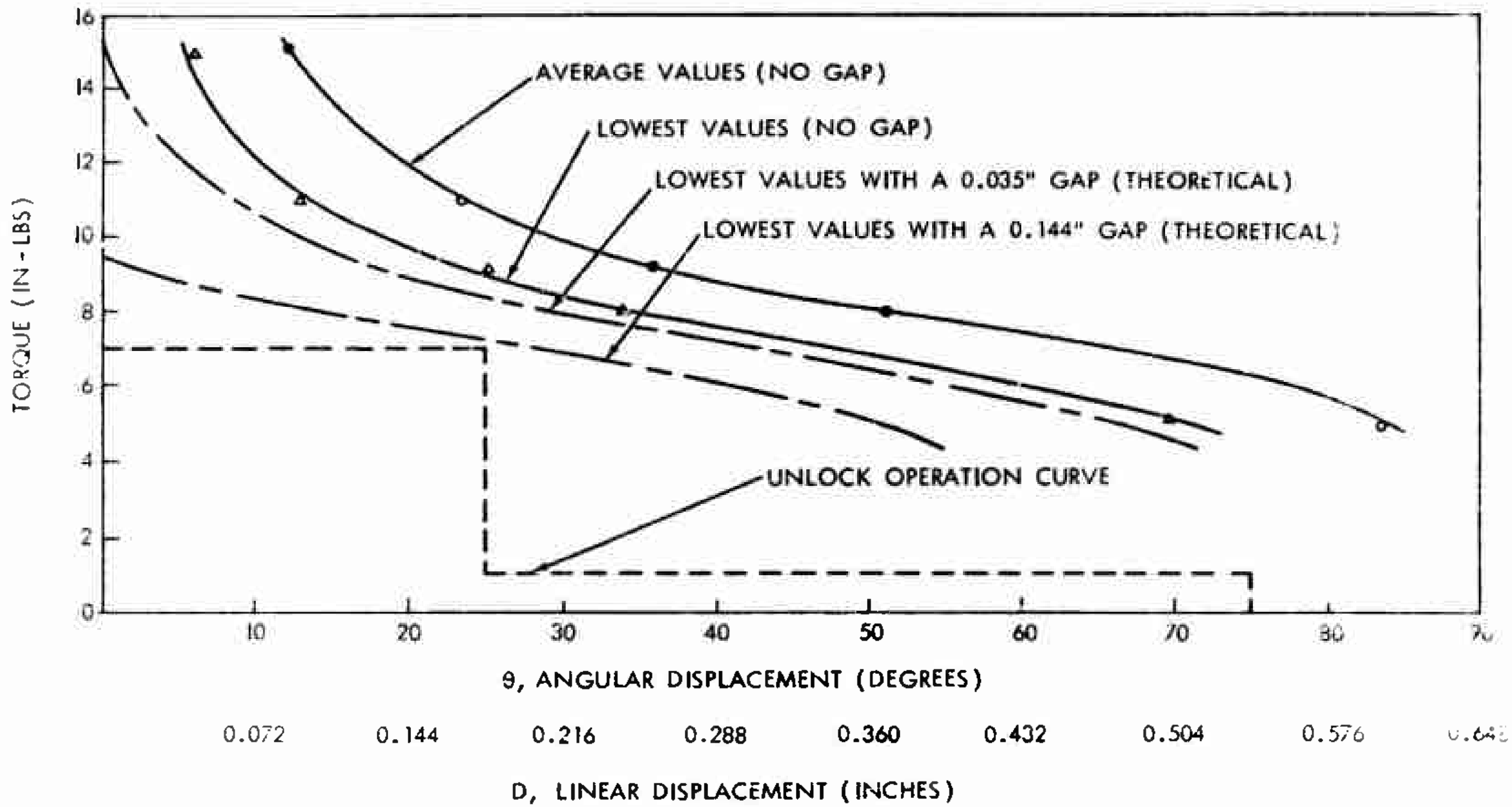


FIG. 4 BELLOWS DRIVER MK 15 MOD O OUTPUT CURVES (SINGLE BELLOWS WITH SIMULATED UNLOCK FRICTION)

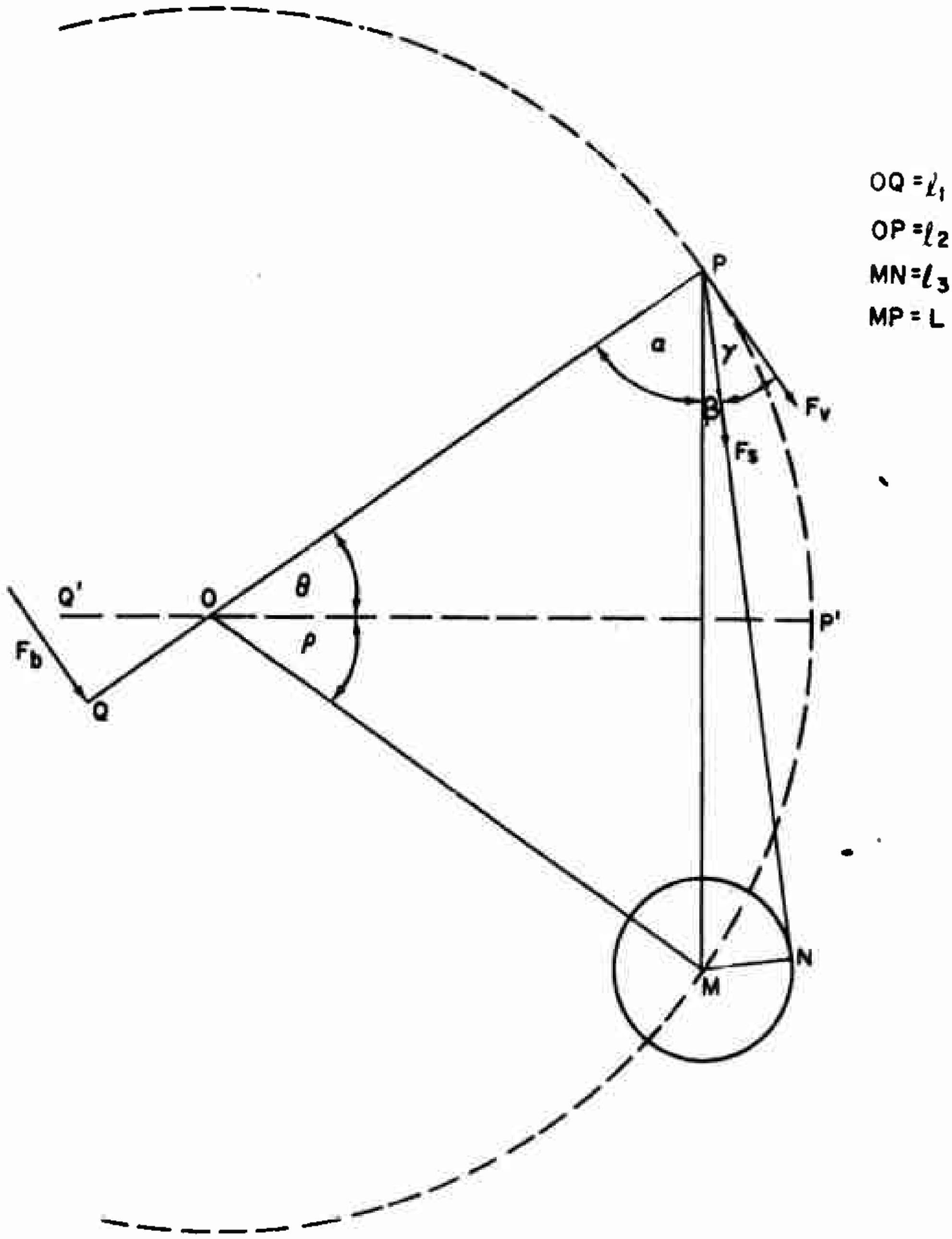


FIG. 5 SCHEMATIC DIAGRAM FOR THE ANGULAR DISPLACEMENT OF THE BELLOWS DRIVER AND PADDLE IN THE BELLOWS DRIVER OUTPUT TEST FIXTURE

TABLE 1 TEST DATA

SPRING FORCE, (F_S) (LBS)	TORQUE (T)(IN/LBS)	AVERAGE ANGULAR DISPLACEMENT, ($\bar{\theta}$) (DEGREES)	LOWEST ANGULAR DISPLACEMENT, (θ_L) (DEGREES)	STANDARD DEVIATION, (σ) (DEGREES)
3.70	5.0	83.55	70.0	$\pm$ 7.01
4.49	8.0	51.15	34.0	$\pm$12.20
4.80	9.0	36.95	25.0	$\pm$ 8.34
5.47	11.0	23.45	13.0	$\pm$ 5.90
6.60	15.0	12.30	6.0	$\pm$ 4.63

APPENDIX A

Derivation of Equation (2)

1. Referring to Figure 5, the paddle QP is initially located at QP'. When the driver is fired against a negator spring force F_s, the paddle stops at an angle θ depending on the value of F_s. That is, a small value of F_s will allow a large angular displacement and a large value of F_s will permit a smaller angular displacement. Letting

l_1 = OQ = driver's moment arm = .500"

l_2 = OP = spring's moment arm = 2.000"

l_3 = MN = spring's drum radius = .297"

L = MP

from geometry, it is clear that

$$F_v = F_s \cos \gamma \tag{3}$$

2. In order to determine γ, first let's look at its complementary angle α plus β. Since

$$L = 2\, l_2 \sin\left(\frac{\theta+\rho}{2}\right)$$

$$\sin\beta = \frac{l_3}{L} = \frac{l_3}{2\, l_2 \sin\left(\frac{\theta+\rho}{2}\right)}$$

$$\therefore \beta = \sin^{-1}\left[\frac{l_3}{2\, l_2 \sin\left(\frac{\theta+\rho}{2}\right)}\right] \tag{4}$$

But in the isosceles triangle ΔPOM

$$2\alpha + \theta + \rho = 180^\circ$$

$$\therefore \alpha = 90^\circ - \frac{\theta+\rho}{2} \tag{5}$$

But $\gamma = 90^\circ - \alpha - \beta$ (6)

Substituting equations (4) and (5) into equation (6), we get

$$\gamma = \frac{\theta+\rho}{2} - \sin^{-1}\left[\frac{\ell_3}{2\ell_2 \sin\left(\frac{\theta+\rho}{2}\right)}\right] \quad (7)$$

Using $\rho = 35^\circ$, $\ell_3 = .297''$, $\ell_2 = 2.000''$

$$\gamma = 17.5^\circ + \frac{\theta}{2} - \sin^{-1}\left[\frac{.297}{4\sin\left(\frac{\theta+35^\circ}{2}\right)}\right] \quad (8)$$

Since γ is a function of θ only, the torque T produced by the driver can be expressed in terms of θ by the aid of equations (1), (3) and (8). It follows

$$T = \ell_1 F_5 \cos\left\{17.5^\circ + \frac{\theta}{2} - \sin^{-1}\left[\frac{.074}{\sin\left(\frac{\theta+35^\circ}{2}\right)}\right]\right\} \quad (9)$$

APPENDIX B

1. The standard deviation σ is defined by the equation

$$\sigma = \sqrt{\frac{\Sigma(\theta_i - \bar{\theta})^2}{N}}$$

where θ_i is the individual angular displacement, and $\bar{\theta}$ is the average value and N is the sample size.

APPENDIX C

1. The linear displacement d can be expressed in terms of the angular displacement θ by the following relationship

$$\frac{d}{\theta} = \frac{\pi R}{180^\circ}$$

where R is the contact radius from the center of the shaft to the midpoint of the curved slot in the unlock, where the driver is assumed to be in contact with the paddle, and d is the arc length through which the driver has traveled. Taking R = .413" from BUWEPS drawing 2420792

$$d = .072\,\theta \quad \text{(in.)}$$

DISTRIBUTION

	Copies
Chief, Bureau of Naval Weapons Department of the Navy Waahington 25, D. C. Attn: Library DLI-3	4
Director, Special Projects Office Department of the Navy Washington 25, D. C.	
Commander U. S. Naval Ordnance Test Station China Lake, California Technical Library	
Commander U. S. Naval Ordnance Test Station Pasadena Annex 3202 East Foothill Boulevard Paaadena, California	
Commanding Officer U. S. Naval Ordnance Laboratory Corona, California	
Commanding Officer Harry Diamond Laboratories Connecticut Avenue and VanNess Streets N. W. Waahington, D. C.	
Defenae Documentation Center Cameron Station Alexandria, Virginia 22314	20
Headquarters, Air Proving Ground Center U. S. Air Force, ARDC Eglin Air Force Baae, Florida	
Commanding General Picatinny Arsenal Dover, New Jersey	
Sandia Corporation Livermore, California	

DISTRIBUTION

Copies

Commanding General
Edgewood Arsenal
Edgewood, Maryland
Attn: Library

Sandia Corporation
Albuquerque, New Mexico

AVCO Corporation
Electronics and Ordnance Division
Richmond, Indiana

Hercules Powder Company
Port Ewen, New York

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D	
(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)	
1. ORIGINATING ACTIVITY (Corporate author) U. S. Naval Ordnance Laboratory White Oak, Silver Spring, Maryland	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED
	2b. GROUP
3. REPORT TITLE OUTPUT TESTS OF DRIVER EXPLOSIVE BELLOWS Mk 15 Mod 0	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)	
5. AUTHOR(S) (Last name, first name, initial) Min, Sherman L.	
6. REPORT DATE 30 October 1964	7a. TOTAL NO. OF PAGES 4 (and appendix) / 7b. NO. OF REFS
8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) NOLTR 64-206
b. PROJECT NO. 737-0841	
c. NOL #417	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	
10. AVAILABILITY/LIMITATION NOTICES Released to DDC without restriction.	
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY BUWEPS

13. ABSTRACT

Explosive drivers Mk 15 Mod 0 (Bellows motor) were tested to determine their capability in turning a loaded shaft.

DD FORM 1 JAN 64 1473

UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Explosive Bellows						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through

____________________________________ ."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through

____________________________________ ."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through

____________________________________ ."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.

ı Ordnance Laboratory, White Oak, Md.
OL technical report 64-206)
PUT TESTS OF DRIVER, EXPLOSIVE BELLOWS
5 MOD 0, by Sherman L. Min. 30 Oct. 1964.
illus., charts, tables, diagrs. NOL task
S/P.

UNCLASSIFIED

rce-displacement curves for the Mk 15 ex-
ive driver were determined by measurement
test fixture simulating a particular ord-
e application. One hundred units were
ed and variability of output was determined.
variability and shape of the force-displace-
curves indicate the importance of close
rol of initial positioning of the driver
tive to the parts it operates in such an
ication.

1. Bellows, Explosive
2. Explosive drivers - Mark 15
I. Title
II. Min, Sherman L.
III. Project

Abstract card is unclassified.

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 64-206)
OUTPUT TESTS OF DRIVER, EXPLOSIVE BELLOWS
MK 15 MOD 0, by Sherman L. Min. 30 Oct. 1964.
v.p. illus., charts, tables, diagrs. NOL task
417 S/P.

UNCLASSIFIED

Force-displacement curves for the Mk 15 explosive driver were determined by measurement in a test fixture simulating a particular ordnance application. One hundred units were tested and variability of output was determined. The variability and shape of the force-displacement curves indicate the importance of close control of initial positioning of the driver relative to the parts it operates in such an application.

1. Bellows, Explosive
2. Explosive drivers - Mark 15
I. Title
II. Min, Sherman L.
III. Project

Abstract card is unclassified.

Ordnance Laboratory, White Oak, Md.
L technical report 64-206)
PUT TESTS OF DRIVER, EXPLOSIVE BELLOWS
MOD 0, by Sherman L. Min. 30 Oct. 1964.
illus., charts, tables, diagrs. NOL task
S/P.

UNCLASSIFIED

ce-displacement curves for the Mk 15 ex-
ve driver were determined by measurement
test fixture simulating a particular ord-
application. One hundred units were
d and variability of output was determined.
variability and shape of the force-displace-
curves indicate the importance of close
ol of initial positioning of the driver
ive to the parts it operates in such an
cation.

1. Bellows, Explosive
2. Explosive drivers - Mark 15
I. Title
II. Min, Sherman L.
III. Project

Abstract card is unclassified.

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 64-206)
OUTPUT TESTS OF DRIVER, EXPLOSIVE BELLOWS
MK 15 MOD 0, by Sherman L. Min. 30 Oct. 1964.
v.p. illus., charts, tables, diagrs. NOL task
417 S/P.

UNCLASSIFIED

Force-displacement curves for the Mk 15 explosive driver were determined by measurement in a test fixture simulating a particular ordnance application. One hundred units were tested and variability of output was determined. The variability and shape of the force-displacement curves indicate the importance of close control of initial positioning of the driver relative to the parts it operates in such an application.

1. Bellows, Explosive
2. Explosive drivers - Mark 15
I. Title
II. Min, Sherman L.
III. Project

Abstract card is unclassified.